

1 **GAGE THICKNESS MEASUREMENT BY USE OF INDUCTIVE SENSORS**

2 CROSS REFERENCE TO RELATED APPLICATIONS

3 This application claims the benefit of copending U.S. provisional patent
4 application serial No. 60/181,942 filed February 11, 2000, the teachings of which are
5 incorporated herein by reference.

6 FIELD OF THE INVENTION

7 This invention relates to the use of a linear analog sensor to measure thickness of
8 non-metallic skin material, such as polymeric skin material. More specifically, the
9 present invention relates to the use of a linear analog sensor to measure the thickness of
10 polymeric skin material suitable for use on an automotive instrument panel, to thereby
11 provide more accurate information regarding skin thickness for other manufacturing
12 steps that require accurate skin thickness determinations, such as laser scoring or
13 weakening of the skin at a desired location for placement of an air-bag deployment
14 system.

15 BACKGROUND OF THE INVENTION

16 In various commercial assembly applications, there remains a constant need to
17 develop a reliable technique to more accurately provide information regarding thickness
18 of a non-metallic component, such as a polymeric material, which includes plastic or
19 elastomeric type skin material. Such information, of course, would be critically needed
20 in those situations where the polymer material at issue requires another downstream
21 manufacturing operation, which may rely upon skin thickness as a critical variable.

1 For example, in the automotive field, a variety of disclosures exist concerning
2 the creation of a tear seam for the purpose of improving the performance of an air bag
3 deployment system. Examples of such air bag cover tear seams are disclosed in U.S.
4 Patent Nos. 5,072,967; 5,082,310; 5,316,822 and 5,632,914. As disclosed therein, tear
5 seams are prepared by forming such seam in the backside of a polymeric skin material.
6 In addition, the seams are provided in various configurations, with the most common
7 having a C, H, U or X-shape and wherein the pattern ultimately defines the number of
8 air bag deployment doors required in the substrate.

9 That being the case, in the course of manufacturing skin material for use on an
10 instrument panel, wherein the skin must be weakened at selected locations, it is critical
11 to have some reliable indication of skin thickness, so that the weakening, scoring or tear
12 seam formation, which occurs in a downstream process, can be properly regulated. That
13 being the case, there remains a constant need to develop reliable techniques to evaluate
14 thickness in non-metallic/polymeric type skin materials.

15 Of course, to date, a number of techniques have been advanced to measure
16 thickness of a given non-metallic part. For example, it has been known to use lasers or
17 other optical means to scan the surface of a fixture, followed by a subsequent scan after
18 the plastic skin or shell is placed therein. Such method has been found to provide
19 inconsistent thickness measurements due to varying reflectivity of the surface and a
20 variety of other unknown factors.

1 Accordingly, it is an object of this invention to overcome the disadvantages of
2 prior art designs and provide a new apparatus and method for detecting part thickness in
3 non-metallic/polymeric type materials.

4 SUMMARY OF THE INVENTION

5 In broad aspect, the present invention relates to a linear analog inductive sensor
6 apparatus that is employed to measure the thickness of a non-metallic/polymeric type
7 material at any point along the surface thereof. In method form, the invention relates to
8 placing the sensor in contact with the surface of the non-metallic surface, whose
9 thickness is to be determined, wherein the non-metallic material is itself placed over a
10 metallic target material. The sensor thereby detects and measures the distance between
11 its contact point on the surface, to the target, which therefore provides an accurate and
12 reliable measure of the non-metallic material thickness. The invention herein therefore
13 can be applied to any non-conducting material, such as plastic or a composite/laminate
14 material, rubber or fabric.

15 In further aspect the present invention relates to a process for measuring and
16 recording the thickness of an automotive trim panel material to generate a cross-
17 sectional thickness profile comprising the steps of contacting a first surface of the
18 material at a plurality of positions with an inductive sensor, contacting a second and
19 opposite surface of the material at a corresponding plurality of positions with a metallic
20 object, converting the output of the sensor into a value that represents the thickness of
21 the material at said plurality of positions, generating a cross-sectional profile of
22 thickness in said material as between said plurality of positions, and communicating

1 said cross-sectional profile of thickness in said material to a controller which is in
2 communication with a cutting assembly to cut said material to a desired thickness,
3 wherein said controller adjusts the thickness of a cut into said material based upon said
4 cross-sectional profile thickness in said material to provide a cut of desired thickness.

5 *Sub A* In ^{an} alternative embodiment the present invention relates to a process for
6 measuring and recording the thickness of an automotive trim panel material to generate
7 a cross-sectional thickness profile comprising the steps of contacting a first surface of
8 the material at a first position with an inductive sensor, contacting a second and
9 opposite surface of the material with a metallic object, converting the output of the
10 sensor into a value that represents the thickness of the material at said first position,
11 contacting said first surface of the material at a second position with said inductive
12 sensor, contacting a second opposite surface of the material at said second position with
13 a metallic object, converting the output of the sensor into a value that represents the
14 thickness of the material at said second position, and generating a cross-sectional
15 thickness profile in said material as between said first and second positions.

16 In yet ^a further alternative embodiment, the generated cross-sectional thickness profile
17 is communicated to a controller which is in communication with a cutting assembly to
18 cut said material to a desired thickness, wherein said controller adjusts the thickness of a
19 cut into said material based upon said cross-sectional profile thickness in said material
20 to provide a cut of desired thickness.

21 BRIEF DESCRIPTION OF THE DRAWINGS

1 **FIG. 1** illustrates the inductive sensor of the present invention before application
2 to the surface of indicated plastic shell material.

3 **FIG. 2** illustrates the inductive sensor of the present invention as applied to the
4 indicated plastic shell material.

5 **FIG. 3** illustrates the use of the inductive sensor herein, as applied to an
6 automated robotic assembly.

7 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

8 As noted, the invention herein relates to a linear analog device for the
9 measurement of part thickness. Preferably, the analog device is an inductive sensor
10 made by OMRON, Model E2CA-X2A, which itself is connected to an E2CA-AN4D
11 amplifier unit.

12 The sensor is then positioned on the surface of the non-metallic part to be
13 measured. With attention to **FIG. 1**, as shown therein, the inductive sensor **10** is shown
14 positioned above the non-metallic material surface **12** to be measured. Such non-
15 metallic material may include any type of material that is non-conductive, such as
16 synthetic polymeric material, including, but not limited to a thermoplastic, thermoplastic
17 elastomer, thermoset material, etc. More specifically, non-metallic material **12** may
18 include a thermoplastic polyester or polyurethane type material, in particularly, a
19 polyurethane skin material, poly(vinyl chloride), or other types of polymeric material
20 used as skin material on automotive instrument panel applications.

21 As also shown in **FIG. 1**, the non-metallic material **12** is positioned over a
22 conductive metallic material **14**, which ultimately serves as the target for the inductive

1 device 10. With attention directed at FIG. 2, inductive sensor 10 is positioned in
2 contact with non-metallic material 12, at location 16, over conductive target 14. At
3 such time, sensor 10 will provide measurement of the distance or thickness 18 from
4 sensor 10 to target 14. Furthermore, although not shown, sensor 10 can be located
5 anywhere along non-metallic material 12, to provide a reliable statistical distribution of
6 thickness 18 for the purposes of properly informing other downstream manufacturing
7 operations that require an accurate assessment of thickness values.

8 In accordance with the present invention, which has been found to be preferably
9 applied to the measurement of a skin thickness in a non-metallic material (e.g.,
10 polyurethane elastomeric skin) prior to application on an automotive instrument panel,
11 various levels of thickness have been successfully evaluated. For example, sensor 10
12 conveniently provides thickness determinations between 0.001" – 0.500", and at all
13 ranges there between, at reducing thickness values of 0.001". For example, thickness
14 determinations have been established between values of 0.002" – 0.499". 0.003"-
15 0.498", etc. In a most preferred embodiment, thickness values between 0.020" – 0.065"
16 are determined, which is a typical range for a non-metallic skin material in an
17 automotive instrument panel application.

18 With respect to the target material 14, as noted, such material is conducting
19 material, such as stainless steel, which thereby communicates with the sensor 10 to
20 provide a selected thickness determination. Preferably, such target material is stainless
21 steel at a thickness of 0.010", but other thickness can be used, provided it is sufficient to
22 communicate with device 10.

1 Also, as shown in FIG. 2, surrounding the target material 14 is a nest or fixture
2 20, which supports the target material 14 so that it is properly positioned to
3 communicate with the sensor 10 as disclosed herein. Fixture 20 may itself be
4 conveniently made from a thermoset resin such as an epoxy resin, with sufficient
5 rigidity to serve as a support structure.

6 In an alternative embodiment, the thickness of the non-metallic material 12, for
7 example an automotive instrument panel, is measured using the sensor 10 while the
8 panel is still in the mold. Instrument panels can be formed using many different
9 molding processes. Many instrument panels are formed using a slush molding process.
10 These molds are typically formed of a metallic material such as nickel. After the panel
11 is formed, but before it is removed from the mold, the thickness of the part can be
12 measured and stored for later use. The sensor 10 uses the nickel mold as the target to
13 determine the thickness of the panel. The sensor can measure the thickness of the panel
14 along a predetermined path. The predetermined path may be a path where an air bag
15 opening will be formed by a later process. The thickness of the part along the
16 predetermined path for a corresponding panel can be saved in memory for later use
17 when forming a score line for an airbag deployment section.

18 Also, as can be appreciated, the sensor device 10 may be conveniently applied to
19 an automated robotic type assembly, such that the robotic arm selectively positions the
20 sensor device 10 at a desired location for thickness evaluation. In that regard, it has
21 been found that an important and useful aspect is to ensure that the sensor device 10 is
22 connected to the robotic arm via a flexible or spring-loaded mechanism, such that the

1 robotic arm can position the sensor 10 on the surface, and the flexible mechanism there-
2 between ensures proper contact with the surface for a desired thickness measurement.
3 Stated another way, the placement of the sensor 10 on a flexible mechanism or spring
4 loaded assembly allows the robotic arm to position and align the sensor 10 on a given
5 surface, and apply pressure thereto, and any excess pressure would be relieved by the
6 flexible mechanism, while ensuring that the sensor 10 provides appropriate surface
7 contact to allow for proper thickness measurement.

8 The preferred inductive sensors for use herein are linear analog inductive
9 sensors. They are available in versions that produce either 4mA to 20mA output signals,
10 or a 0V to 10V type output signals. Accordingly, such current output or voltage output
11 is then conveniently correlated to part thickness by standard calibration techniques using
12 samples of known part thickness.

13 In an even more preferred embodiment of this invention, and as noted above, the
14 inductive sensor herein is made to output its thickness reading to an analog/digital
15 (A/D) converter, which digital signal is then inputted to a computer controller
16 responsible for adjusting the thickness of a score line to be imparted to a polymeric skin
17 material, which material is employed for the purpose of preparing an airbag deployment
18 section on an automotive instrument panel. Such digital signal can be conveniently
19 delivered to such computer controller by a computer serial connection, USB cable
20 connection, etc. That being the case, the inductive sensor herein, as coupled to, e.g., the
21 computer controller on a laser scoring apparatus, would provide the laser apparatus
22 reliable information on polymeric skin thickness, for the purpose of forming a

1 controlled thickness tear seam in any desired configuration. The invention herein
2 therefore is directed at an automated system, comprising the inductive sensor, coupled
3 to a downstream manufacturing operation (such as laser scoring), through the use of a
4 computer interface, which accepts thickness determinations and considers such
5 information as applied to said given downstream manufacturing operation.

6 In addition, the inductive sensor may also be coupled to an upstream molding
7 operation, through a computer interface, which accepts thickness determination and
8 considers such information as applied to said molding operation thereby instructing said
9 molding operation to either increase or decrease thickness as may be desired. Control of
10 thickness may be accomplished, e.g., by adjusting the amount of material charged into
11 the mold, mold temperature, mold cooling, molding pressure and/or time for the overall
12 molding cycle.

13 Finally, attention is directed to **FIG. 3**, which as noted above, illustrates the use
14 of the inductive sensor holder as attached to an automated robotic assembly.
15 Specifically, an SMC air cylinder (NCMC 106-0200C) is shown generally at **22**, which
16 contains a pair of air discharge openings **24**, which contains a spring inserted therein
17 (not shown). A shaft distance of approximately 2.25" is set between the end of the
18 cylinder **22** and the top of the sensor holder **26**. The sensor holder is threaded onto the
19 shaft, along with a locking nut **28**. A nut is placed at **29**.

20 At **30** is illustrated the preferred Nachi robot mounting adaptor with a length of
21 about 7/8". A machined brass adaptor is shown at **32**, along with a threaded insert at **34**,
22 and a plurality of locking screws identified at **36**. The overall length of the robotic

- 1 assembly shown in **FIG. 3** is about 10.75", with a spring size therein (not shown) of
- 2 2.0" x 5/8".

10.75" x 5/8" x 2.0"